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ABSTRACT

Objective: Pressure ulcer development (pressure injury) is considered an indicator for quality of care, as pressure ulcers are potentially preventable. Yet pressure ulcer is a leading cause of morbidity, discomfort, and additional healthcare costs for inpatients. Methods are lacking for accurate surveillance of pressure ulcer in hospitals to track occurrences and evaluate care improvement strategies. The main study aim was to validate hospital discharge abstract database (DAD) in recording pressure ulcers against nursing consult reports, and to calculate prevalence of pressure ulcers in Alberta, Canada in DAD. We hypothesized that a more inclusive case definition for pressure ulcers would enhance validity of cases identified in administrative data for research and quality improvement purposes.

Setting: A cohort of patients with pressure ulcers were identified from enterostomal (ET) nursing consult documents at a large university hospital in 2011.

Participants: There were 1217 patients with pressure ulcers in ET nursing documentation that were linked to a corresponding record in DAD to validate DAD for correct and accurate identification of pressure ulcer occurrence, using two case definitions for pressure ulcer.

Results Using pressure ulcer Definition 1 (7 codes) we found an adjusted prevalence of 1.4% and using Definition 2 (29 codes) we found a prevalence of 4.2% after adjusting for misclassifications. The results were lower than expected. Definition 1 had a sensitivity of 27.7% and a specificity of 98.8%, while definition 2 had a sensitivity of 32.8% and a specificity of 95.9%. Pressure ulcer diagnosis in both DAD and ET consultation increased with age, number of comorbidities, and length of stay.

Conclusion DAD underestimates the prevalence of pressure ulcers. Since a variety of codes are used to identify pressure ulcers in DAD, our case definition with more inclusive codes captures a higher frequency of pressure ulcer cases. However, sensitivity remains low emphasizing the need for improved pressure ulcer documentation and coding.

Strengths and limitations of this study

- We examined a large sample of patients for prevalence of pressure ulcers against enterostomal specialist consult descriptions to derive and validate a case-definition in disease classification codes.
- This study adds evidence of underestimation of pressure ulcer prevalence in administrative hospital data that could potentially be improved with more specific documentation and coding.
- A potential bias may be present from use of enterostomal nurse consultation notes that included only stage III and IV pressure ulcers.
- The descriptive textual database created in this study is the foundation for future work on auto-detection of pressure ulcers in hospital records, to enhance the accuracy of prevalence estimates.

BACKGROUND

The development of a pressure ulcer (also called pressure injury) has been considered an indicator for quality of care, as pressure ulcers are potentially preventable, a leading cause of morbidity for inpatients,(1) and is a cause of substantial discomfort, prolonged hospitalizations, additional healthcare costs, and in some cases, death.(1) The National Pressure Ulcer Advisory Panel defines a pressure ulcer as "a localized injury to the skin and/or underlying tissue over a bony prominence, as a result of pressure, or pressure in combination with shear".(2) The severity of pressure ulcers can vary from skin erythema to full thickness tissue loss, with damage extending into muscle and bone.(2) It is estimated that pressure ulcers affect 250,000 to 500,000 patients, with an annual prevalence of 21-26% in health-care institutions in Canada.(3, 4) In the USA, pressure ulcer prevalence ranged from 10 to 18% in general acute care, 2.3 to 28% in long term care, and 0 to 29% in home care between 1990 and 2000.(5) As more severe cases require intensive treatments, have a prolonged healing time and are associated with higher incidence of complications,(6) the estimated cost of treatment varies from £1,214 to £14,108 per case in the UK,(6) and $124,327 to $129,248 USD in the USA for stage IV pressure ulcers.(7) In Canada, the estimated average monthly cost of pressure ulcer management among individuals with a spinal cord injury was $4,475 CDN in 2010.(8)

To date, information about pressure ulcers has been primarily obtained through cross-sectional surveys and chart reviews. The medical chart has been considered the "reference standard" as a source of research and quality improvement data due to the clinical information it contains. Thus retrospective reviews of medical records have been undertaken to identify prevalence and incidence of pressure ulcers as well as patient characteristics and associated risk factors among various patient populations,(4, 9-22) evaluate preventive and management strategies,(23-27) and evaluate the Braden scale in assessing risk for pressure ulcer development.(28) However, chart review is costly and time-consuming to obtain.

Taking into account these barriers, administrative health data has been used as an alternate data source for pressure ulcer epidemiology and surveillance. Administrative health data is routinely-collected and population-based and can offer a more comprehensive picture of view of large population.(29) As administrative health data is collected for purposes other than research, it may be limited in its generalizability, continuity, accuracy and completeness.

To date, several studies have used administrative health data to determine adverse events.(30-35) Some studies in the US have used the national Medicare Patient Safety Monitoring System database to determine the national and state incidence of hospital-acquired pressure ulcers,(36) and the 2003 Nationwide Inpatient Sample database to identify risk factors for pressure ulcer development among African Americans.(37) One study examined trends in the prevalence and localization of pressure ulcers and comorbidities among hospitalized patients in Germany from 2005 to 2011 by using nationally-collected hospital data.(38) While administrative health data has been found to be valid in one study for identifying adverse events, including pressure ulcers, among older hospitalized patients,(39) findings from other studies indicated that administrative health data may not be reliable for examining pressure ulcer development among hospitalized patients, (40, 41) and occurrence in long-term care.(42)

In consideration of the paucity and discrepancies in the literature, the purpose of our study was to validate Canadian administrative health data, also called hospital discharge abstract database (DAD), for determining if DAD could be used for pressure ulcer epidemiological studies and surveillance of pressure ulcers for quality improvement. However, the International Classification of Diseases 10th version, in Canada (ICD-10-CA) codes in DAD include those specific to pressure ulcer only, as well as those which refer to more generic skin conditions and may indeed be used for the coding of pressure ulcer. There is currently no standard for coding pressure ulcer in DAD. Our three specific objectives were 1) to validate DAD in recording pressure ulcer, 2) to calculate prevalence of pressure ulcer using DAD and 3) to adjust the prevalence to account for DAD validity. We hypothesized that a more inclusive case definition for pressure ulcers would enhance validity of cases identified in administrative data for research and quality improvement purposes.

MATERIALS AND METHODS

Study design

Our study team completed a cross-sectional retrospective analysis of enterostomal therapy (ET) nursing documentation and DAD independently to identify every pressure ulcer occurrence documented in each source for the year of 2011 (period prevalence). The DAD collects information from the patient's chart for each hospital discharge through professional coders. Validation was achieved by comparing it to the "reference standard" of data abstracted from wound care documentation by ET nurses. Unlike the existing literature, our study draws on Canadian data, and validates DAD by comparing it to documentation by ET nurses, which is likely to be the most accurate "reference standard" of chart recording on pressure ulcer management.

ET nurses are registered nurses who have received additional training to specialize in the provision of wound (including pressure ulcer), ostomy, and continence care. ET nurses are wound care specialists who are often present in larger hospitals to consult for treatment guidelines. ET nurse consults occur for more advanced pressure ulcers and therefore, more detailed documentation is typically present. Each occurrence from the ET nursing documentation was linked to its corresponding record in DAD through personal unique identifier (personal health number), in order to validate DAD for correct and accurate identification of pressure ulcer occurrence. We validated and compared two DAD coding definitions (Table 1) and calculated sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

Setting and study population

This study was conducted at a tertiary referral university hospital situated in a large city in Canada. It is one of the country's largest medical facilities with over 1000 acute inpatient beds.

Data sources

Enterostomal nurse documentation

We obtained nursing documentation on inpatients that received a consultation with an ET nurse (here on referred to as "ET nurse consults") in the year of 2011. These would include but are not limited to: pressure ulcers, diabetic foot ulcers, venous leg ulcers, and other skin conditions.

Table 1. International Classification of Diseases 10th Version, Canada (ICD-10-CA) Codes

Definition 1
L89 Decubitus [pressure] ulcer and pressure area
L89.0 Stage I decubitus ulcer and pressure area
L89.1 Stage II decubitus [pressure] ulcer
L89.2 Stage III decubitus [pressure] ulcer
L89.3 Stage IV decubitus [pressure] ulcer
L89.8o Decubitus [pressure] ulcer, unstageable
L89.9 Decubitus ulcer and pressure area, unspecified

Definition 2
L89 Decubitus [pressure] ulcer and pressure area
L89.0 Stage I decubitus ulcer and pressure area
L89.1 Stage II decubitus [pressure] ulcer
L89.2 Stage III decubitus [pressure] ulcer
L89.3 Stage IV decubitus [pressure] ulcer
L89.8o Decubitus [pressure] ulcer, unstageable
L89.9 Decubitus ulcer and pressure area, unspecified
L97 Ulcer of lower limb, not elsewhere classified
L98.4 Chronic ulcer of skin, not elsewhere classified
S00 Superficial injury of head
S01 Open wound of head
S10 Superficial injury of neck
S11 Open wound of neck
S20 Superficial injury of thorax
S21 Open wound of thorax
S30 Superficial injury of abdomen, lower back and pelvis
S31 Open wound of abdomen, lower back and pelvis7.4
S40 Superficial injury of shoulder and upper arm
S41 Open wound of shoulder and upper arm
S50 Superficial injury of forearm
S51 Open wound of forearm
S60 Superficial injury of wrist and hand
S61 Open wound of wrist and hand
S70 Superficial injury of hip and thigh
S71 Open wound of hip and thigh
S80 Superficial injury of lower leg
S81 Open wound of lower leg
S90 Superficial injury of ankle and foot
S91 Open wound of ankle and foot

Specific to pressure ulcers, patients who have more severe ulcers, namely stage III and IV, are referred by nursing staff or physicians for an ET nurse consult. All of these consult requests are stored in a binder and maintained by the ET nursing team. Every ET nurse consult from the binder from 2011 was included in our study.

A medical student was trained by the principal investigator, who has expertise on pressure ulcer, on how to review the consult documentation to determine whether the wound(s) of interest was a pressure ulcer. The medical student analyzed each consult to identify those that described a pressure ulcer. Documentation from follow-up consults and duplicate consults were treated as one consult. For consult documentation that did not clearly indicate whether a pressure ulcer was being treated, the respective medical chart was obtained and reviewed by the medical student and principal investigator to determine whether a pressure ulcer was being treated. Consultations regarding wounds unrelated to pressure ulceration were excluded from our sample OR categorized as not pressure ulcer-related.

Included consultations concerning a pressure ulcer were then categorized by the location of the pressure ulcer and if possible, its severity according to staging system of the National Pressure Ulcer Advisory Panel (NPUAP).(2) It was expected that all of the pressure ulcers that triggered a consult with the ET nurses would be stage III and IV. The anatomic categories included sacral ulcers, leg ulcers, ankle ulcers, heel ulcers, foot ulcers, and other ulcers. Patients with pressure ulcer in multiple locations had each ulcer entered separately in our database.

A trained medical student extracted the following information: patient hospital identification code, whether the consultation was pressure-ulcer related, location(s) of the pressure ulcer(s), and their severity. This information was used as our "reference standard" to verify the existence of pressure ulcers among the patients included in the study, which were then compared to the DAD data of the corresponding patients.

Discharge Abstract Data

This hospital's DAD was obtained from the data repository managed by the region's single health authority. This repository integrates data from multiple source systems, linking them as well as aggregating them to support measurement, reporting, and survey purposes. For each discharge, DAD abstracts and summarizes demographic, clinical, and administrative information such as date and time of admission, date of discharge, length of stay, and a maximum of 50 diagnostic codes (ICD-10-CA) and 20 procedure codes. To identify cases of pressure ulcer(s) in DAD for the year 2011, we used an ICD-10 coding definition that was developed by a group of wound care clinicians, ET nurses and nurse researcher. The process involved independent review of the ICD-10 codes by each of these people to identify codes which they considered to be related to pressure ulcers. Then a meeting was held to discuss the identified codes for pressure ulcers. Ultimately, we decided to test two coding definitions. One definition is more specific (with only L89 codes), and should yield greater detection accuracy. The second definition is more inclusive (with L89 and other non-specific codes for wounds) and will likely capture a larger number of cases. The ICD-10 codes used for both definitions included in our study is included in Table 1.

Linkage

Consultation data was linked with DAD using each patient's personal health number (PHN). To ensure that we are linking each consultation to the correct admission, we decided to only link consultations with the admission during which the consultation occurs. In other words, our linkage criteria specified that the consultation date must fall within the admission and discharge dates.

Statistical Analysis

Before conducing validation, we identified pressure ulcer cases in DAD. Using the two previously described ICD-10 coding definitions; we identified pressure ulcer cases in discharge data for all admissions at the large university hospital in 2011, and calculated a pressure ulcer prevalence using each definition.

The existence of pressure ulcers was compared between the two databases, and we calculated measures of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for each definition. This allows us to compare the predictive accuracy of each definition. We then used sensitivity to adjust our preliminary prevalence. This adjusted prevalence represents what the prevalence would have been had there been perfect sensitivity. We decided to only adjust using sensitivity, due to the fact that we had a low number of positive cases. Adjustment by sensitivity and specificity would have yielded nonsensical results.

All data analysis was conducted using SAS 9.3. SAS is analytical software that is well suited to working with large databases.

RESULTS

Our consultation data contained 1575 ET nurse consults. Of these 318 were found to be duplicates and 2 patients were under the age of 18. These records were removed. Thirty-eight were cases of diabetic ulcers. It was decided by the study team that diabetic ulcers would not be included and these cases were also removed. The remaining sample included 1217 unique ET nurse consults which were linked to their matching admission in DAD (Figure 1).

Comparing pressure ulcer information in DAD against that in consultation, we calculated sensitivity of 27.7%, specificity of 98.8%, PPV of 91.7% and NPV of 73.9% for definition one, and a sensitivity of 32.8%, a specificity of 95.9%, a PPV of 79.3% and a NPV of 74.6% for definition two (Table 2). Regardless of definition, validity of ICD coding for pressure ulcers was relatively stable across groups by age and sex. However, validity of ICD coding improved with increased length of stay.

Table 2. Validity of administrative health data for two case definitions for pressure ulcer using consultation as reference standard (N= 1217)

	Sensitivity	Specificity	PPV*	NPV*
Definition 1 (7 ICD-10-CA codes)				
Overall	27.7%	98.8%	91.67%	73.9%

Age	18 - 34	20.0%	96.1%	60.0%	80.3%
	35-64	32.0%	98.5%	88.89%	79.84%
	65 and over	25.4%	99.4%	96.7%	67.4%
Sex	Male	29.0%	98.4%	90.1%	73.3%
	Female	26.1%	99.2%	93.9%	74.6%
Length of stay	1 - 30 days	19.5%	99.7%	95.4%	78.4%
	31 - 90 days	35.9%	96.9%	90.2%	65.7%
	91 - 180 days	40.5%	90.0%	83.3%	55.1%
	181 days or more	36.4%	100.0%	100.0%	51.72%
Definition 2 (29 ICD-10-CA codes)					
Overall		32.8%	95.9%	79.3%	74.6%
Age	18 - 34	40.0%	92.2%	60.0%	83.9%
	35-64	39.3%	95.6%	77.6%	81.2%
	65 and over	28.0%	96.4%	83.3%	67.5%
Sex	Male	34.4%	95.7%	80.0%	74.3%
	Female	30.7%	96.1%	78.3%	75.1%
Length of stay	1 - 30 days	23.8%	97.2%	74.6%	78.8%
	31 - 90 days	41.4%	92.6%	81.5%	66.7%
	91 - 180 days	46.0%	90.0%	85.0%	57.5%
	181 days or more	45.5%	86.7%	83.3%	52.0%

Note: PPV: Positive predictive value, NPV: negative predictive value

Table 3 shows the prevalence and adjusted prevalence of pressure ulcers in DAD, stratified by age, sex, and length of stay using both definitions. We see that the adjusted prevalence is approximately double overall, and for most stratifications. The stratified prevalence indicates males were more likely to have pressure ulcers compared with females, and that longer length of stay is correlated with higher pressure ulcer prevalence.

Table 3. Prevalence and adjusted prevalence for two case definitions for pressure ulcers in hospital discharge administrative data (DAD)

		Coded in DAD		**Adjusted based on sensitivity**		
Definition 1 (7 ICD-10-CA codes)		**Number of cases**	**Prevalence**	**Number of cases**	**Adjusted Prevalence**	**Sample Size**
Overall		163	0.4%	539	1.4%	38820
Age	18 - 34	9	0.1%	27	0.3%	8667
	35-64	63	0.4%	175	1.0%	16781
	65 and over	81	0.6%	308	2.3%	13372
Sex	Male	100	0.6%	311	1.9%	16734
	Female	63	0.3%	227	1.0%	22096
Length of stay	0 - 30 days	57	0.2%	279	0.8%	36752
	31 - 90 days	74	4.3%	186	10.8%	1724
	91 - 180 days	22	8.5%	45	17.5%	258
	181 days or more	10	11.6%	27	31.9%	86

Definition 2 (29 ICD-10-CA codes)						
Overall		670	1.7%	1620	4.2%	38820
Age	18 - 34	179	2.1%	269	3.1%	8667
	35-64	272	1.6%	537	3.2%	16781
	65 and over	219	1.6%	652	4.9%	13372
Sex	Male	437	2.6%	1016	6.1%	16724
	Female	233	1.1%	594	2.7%	22096
Length of stay	0 - 30 days	504	1.4%	1580	4.3%	36752
	31 - 90 days	117	6.8%	230	13.4%	1724
	91 - 180 days	31	12.0%	57	22.2%	258
	181 days or more	10	11.6%	18	21.3%	86

Table 4 indicates pressure ulcer coding against age, sex, number of co-morbidities, and length of stay, in both DAD and consultation data. Based on odds ratios, we see that while pressure ulcer coding in DAD is similar between age groups, older patients are more likely to be coded with pressure ulcers in the nursing consultations. Further, males are significantly more likely to be coded with pressure ulcers in DAD, whereas, the difference between the sexes is minimal in the consultations. For both DAD and nursing consultations, coding of pressure ulcers increased as the patient presents a greater number of comorbidities, and a longer length of stay.

Table 4. Stratification of pressure ulcer (pressure ulcer) cases in discharge abstract data and in nursing consultations

Definition 1 (7 ICD-10-CA codes)		**Pressure ulcer coded in DAD**			**Pressure ulcer found in Consultation**		
		Yes	**No**	**OR**	**Yes**	**No**	**OR**
Age	18 - 34	9	8658	1.00	15	53	1.00
	35-64	63	16661	3.64	150	410	1.29
	65 and over	81	13324	5.85	232	359	2.28
Sex	Male	100	16634	1.00	221	438	1.00
	Female	63	22096	0.47	176	384	0.91
Comorbidities	0	0	5826		2	52	1.00
	1 - 3	11	18401	1.00	44	241	4.75
	4 - 6	26	9457	2.31	92	210	11.39
	7 - 9	39	2976	21.92	87	128	17.67
	10 or more	87	1997	72.88	172	191	23.41
Length of stay	0 - 30 days	57	36695	1.00	210	615	1.00
	31 - 90 days	74	1650	28.87	128	162	2.31
	91 - 180 days	22	236	60.01	37	30	3.61
	181 days or more	10	76	84.71	22	15	4.30
Definition 2 (29 ICD-10-CA codes)							
Age	18 - 34	179	8488	1.00	15	53	1.00

	35-64	272	16509	0.78	150	410	1.29
	65 and over	219	13153	0.79	232	359	2.28
Sex	Male	100	16624	1.00	221	438	1.00
	Female	63	22033	0.48	176	384	0.91
Comorbidities	0	0	5826		2	52	1.00
	1 - 3	108	18304	1.00	44	241	4.75
	4 - 6	197	9286	3.60	92	210	11.39
	7 - 9	154	2861	9.12	87	128	17.67
	10 or more	211	1873	19.09	172	191	23.41
Length of stay	0 - 30 days	504	36248	1.00	210	615	1.00
	31 - 90 days	117	1607	5.24	128	162	2.31
	91 - 180 days	31	227	9.82	37	30	3.61
	181 days or more	10	76	9.46	22	15	4.30

OR = Odds ratio

Lastly, Table 5 lists the eight most common locations of pressure ulcers from the nursing consultations. Of note, there were a wide range of pressure ulcer locations. The eight most common locations only accounted for 32.6% of all pressure ulcer cases. The most common location by far was trochanteric pressure ulcer.

Table 5. Frequency of pressure ulcer locations based on nursing consultations

Ulcer location	**Number of Cases**	**Prevalence**
Ankle	14	1.1%
Foot	10	2.5%
Heel	42	10.6%
Ischial	4	1.0%
Leg	24	6.0%
Sacral	13	3.3%
Trochanteric	282	71.0%
Other	8	2.1%
Total	397	100.0%

DISCUSSION

The objective of our study was to determine whether routinely collected administrative health data could be used for improved measurement of pressure ulcers. Since there is no standard code definition for pressure ulcer, we used expert consensus to determine two coding definitions from administrative health data to estimate the prevalence. Next, we validated these definitions against wound care documentation by ET nurses. After adjusting for misclassifications of pressure ulcers, using Definition 1 we found prevalence of 1.4% and using definition 2 we found a prevalence of 4.2%. Definition 1 had a sensitivity of 27.7% and a specificity of 98.8%, while Definition 2 had a sensitivity of 32.8% and a

specificity of 95.9%. This means that the more specific Definition 1 more accurately defines cases at the expense of missing some positive cases. Further, Definition 2 includes more positive cases at the risk of a larger number of false positives. Both definitions show low sensitivity and high specificity. These findings indicate that administrative health data underestimates the prevalence of pressure ulcers. Although the more inclusive Definition 2 had slightly higher sensitivity compared to Definition 1, the low sensitivity reflects the potential for the high frequency of missed pressure ulcer cases.

Compared with other studies of pressure ulcer prevalence, using the same set of ICD-10 codes (Definition 1) our finding of 0.4% for unadjusted prevalence is lower than another Canadian study that reported 3.5% cross-sectional prevalence, which can produce an overestimation.(4) As well, our prevalence of 0.4% is substantially low relative to previous studies described above (3, 5). This can be attributed to several factors: that ET nurse consults in our study included only severe (stage III and IV) pressure ulcers while the studies included pressure ulcers of all severities, there were differences in the population(s) studied, and there were different methods and data sources used. For example, the review by Woodbury et al found an estimated pressure ulcer prevalence rate of 26% based on studies between 1990 and 2003 across a range of healthcare settings in Canada, including mostly pressure ulcers determined by clinical data versus coded data.(3) Similarly, Cuddigan et al found prevalence rates ranging from 10 to 18% from analyzing prevalence data spanning a decade (1990-2000) and across care settings, again, based on mostly direct examination or chart review data.(5) Our prevalence rate was based on administrative health data from one tertiary acute care institution over one year. With such wide variations in care settings and time frames, these differences in prevalence rates are not surprising.

Another explanation to account for the underestimated prevalence rate is the inherent nature of the administrative health data. Our finding of either 27.7% or 32.8% sensitivity indicates a large proportion of pressure ulcers are not captured in the administrative health data. While this is a high percentage of missing cases, it is not an unreasonable finding.(32) One of the primary purposes of collecting administrative health data is to inform resource utilization, thus database administrators in Canada use predefined classification codes to register conditions that contribute to the length of stay in the hospital. Thus, less severe pressure ulcers, namely those identified as stage I and II are unlikely to be abstracted into the database. Rather, the low sensitivities reflect the occurrence of stage III and IV pressure ulcers, the most severe cases that would indeed lead to hospitalization or contribute to the length of stay. While an adjusted prevalence rate of 4.2% is relatively low when compared to the overall prevalence of all stages of pressure ulcers across various health care settings,(3) it is comparable to the prevalence rates of severe pressure ulcers found in acute care facilities in other studies.(4, 43, 44)

A unique feature of our study was defining the pressure ulcer cohort by ET nurse consults. This method ensured that clear pressure ulcer cases were included. As a result, there may have been more medical documentation in the health record on wound description and treatment on these clear cases of pressure ulcers. Therefore, we suspect there may have been a greater chance for ICD coding abstractors to detect the pressure ulcer when ET nurses are consulted for the more severe ulcerations. That being said, less severe pressure ulcer cases may have been missed when no formal consultation is made, which are often only recorded by nurses and not seen by ICD coding abstractors.

Administrative health data has been used for various purposes, including chronic disease surveillance, quality of care assessments, and population health reports. This data source has been found to be well-coded for hypertension(45) and diabetes.(46) Similarly for pressure ulcer, administrative data analysis may serve to identify the magnitude of prevalence and monitor annual trends to inform quality of care evaluations. Whether the purpose is to evaluate quality of care over time within the same institution, or to make comparisons between institutions, we need to ensure that the data is sufficiently standardized and its quality is comparable across jurisdictions. Maintaining data quality is particularly salient, as the sensitivity, specificity, and the negative and positive predictive values of the data sources impact their comparability of prevalence rates. Given the high predictive value, this data source could be used to screen for potential pressure ulcer cases, which can be verified and their causes identified through chart reviews. Furthermore, this process would generate a cohort of severe pressure ulcer cases for follow-up study.

We acknowledge that our study has some limitations. First, there are fundamental limitations when using administrative data for surveillance of conditions related to patient safety. Specifically, improved documentation can result in a higher frequency of reported cases, making it appear as though hospitals with a better documentation have worse performance. Similarly, Quan et al drew a conclusion in a chart review study validating ICD-10 hospital discharge abstract data for the Agency for Healthcare Research and Quality (AHRQ) patient safety indicators in hospital discharge abstract data.(31) Due to findings of low sensitivity, they recommended that caution be used when rates of patient safety indicators are presented for 'quality of care reporting' as under-coded data generates falsely low patient safety indicator rates. Our study supports that administrative data is problematic when used for patient safety indicator surveillance. This illustrates the need for widespread improvements in both documentation and data abstraction of pressure ulcer occurrences for accurate data reporting.

Another limitation is that this study was conducted in one institution in an urban area over one year thus it limiting generalizability, though this institution is one of the largest hospitals in Canada. An additional limitation is that we used ET documentation as the reference standard. While ET nurses may be the most knowledgeable about identifying and treating pressure ulcers, at this study's setting, they are only consulted when a patient has a stage III or IV pressure ulcer. As such there is potential for bias as our study findings did not capture cases of less severe pressure ulcers, limiting its applicability to capture all pressure ulcers. We recognize that not all hospitals may offer specialised wound care services like ET nurses further limiting our study's generalizability.

There are several key practice implications from our study. One is that pressure ulcers are not consistently coded using only the ICD-10 L89.x codes, but also codes for other skin injuries. Thus, there will be positive cases missed if only L89 codes are used, as evidenced by low sensitivity of Definition 1. Secondly, more pressure ulcer cases would also be captured by improved documentation to clearly state the presence of a pressure ulcer versus just wound description. Third, coding specialists should be trained to use only L89 codes for pressure ulcers. Lastly, as recommended by Backman, documentation by nurses or other health professions should be considered valid sources for ICD coding to accurately capture hospital-related adverse events, such as pressure ulcers. (4) Until these changes are made, a more inclusive case definition like Definition 2, may be useful to identify pressure ulcer cases.

FUTURE RESEARCH

To proceed with quality improvement interventions, better methods are needed to quickly and accurately identify pressure ulcers in hospital charts and in coded data. Chart review and even the process of coding patient data is time consuming and costly. Future research must include further validation of a case definition for pressure ulcer. Then, these validated cases can be used to develop algorithms for fast automated detection of pressure ulcer in electronic hospital chart data. Currently at our centre, a large (n=3000) review of randomly selected hospital charts is underway to evaluate prevalence and validate ICD-10 codes for pressure ulcer in a larger sample. Next steps include using the validated terminology that describes pressure ulcer to develop auto-detection algorithms. Auto-detection, both in post-discharge and real-time admissions, will enable more effective tracking of pressure ulcer for the best possible treatment and quality improvement strategies for prevention. Ultimately, the same research methods could then be applied to other adverse events for fast accurate measurement.

CONCLUSION

This study provides a case-definition for pressure ulcer surveillance in Canada using administrative health data. Our findings support the use of a more inclusive definition within administrative data for identifying pressure ulcers, specifically, the more severe ones (stage III and IV) per NPUAP's staging system. However, low sensitivity of DAD for identification of pressure ulcer suggests that this data source may not be accurate for determining overall prevalence, and it should be used with caution if it is being compared to other prevalence studies.

Contributors

CH designed the study and data acquisition methods, led analysis, interpretation of data, and provided critical oversight of drafting and revising the manuscript. CH had final approval of the submission.
JJ performed analysis and interpretation of the data.
CE participated in interpretation of the data, drafting, revisions, and submission of the manuscript.
HW participated in drafting, critical appraisal, and revision of the manuscript.
BW performed the majority of data acquisition and participated in drafting, critical appraisal, and revision of the manuscript.
HQ contributed substantially to the conception and design of the study, the interpretation of data, critical appraisal and revision of the manuscript, and final approval for submission.

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Competing interests None declared

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Ethics approval The University of Calgary Health Research Ethics Board approved this study (File number: REB13-0211).

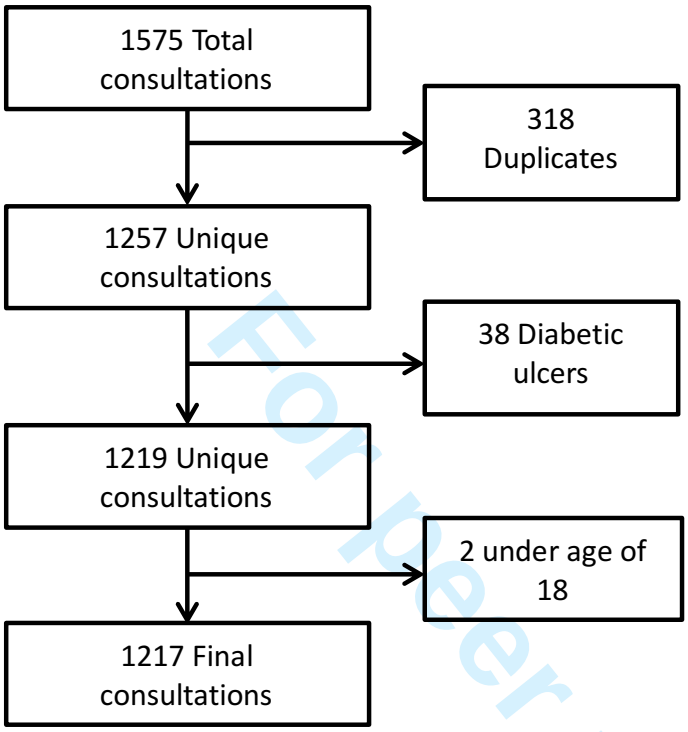
Data sharing statement No additional data are available.

REFERENCES

1. Redelings MD, Lee NE, Sorvillo F. Pressure ulcers: more lethal than we thought? Advances in skin & wound care. 2005;18(7):367-72.
2. Panel NPUA. NPUAP Pressure Ulcer Stages/Categories [Available from: http://www.npuap.org/resources/educational-and-clinical-resources/npuap-pressure-ulcer-stagescategories/.
3. Woodbury MG, Houghton PE. Prevalence of pressure ulcers in Canadian healthcare settings. Ostomy Wound Management. 2004;50:22-39.
4. Backman C, Vanderloo SE, Miller TB, Freeman L, Forster AJ. Comparing physical assessment with administrative data for detecting pressure ulcers in a large Canadian academic health sciences centre. BMJ Open. 2016;6(10): e012490.
5. Cuddigan J, Berlowitz DR, Ayello EA. Pressure ulcers in America: prevalence, incidence, and implications for the future. Advances in skin & wound care. 2001;14(4):208.
6. Dealey C, Posnett J, Walker A. The cost of pressure ulcers in the United Kingdom. J Wound Care. 2012;21(6):261-2, 4, 6.
7. Brem H, Maggi J, Nierman D, Rolnitzky L, Bell D, Rennert R, et al. High cost of stage IV pressure ulcers. The American Journal of Surgery. 2010;200(4):473-7.
8. Chan BC, Nanwa N, Mittmann N, Bryant D, Coyte PC, Houghton PE. The average cost of pressure ulcer management in a community dwelling spinal cord injury population. International wound journal. 2013;10(4):431-40.
9. Alderden J, Whitney JD, Taylor SM, Zaratkiewicz S. Risk profile characteristics associated with outcomes of hospital-acquired pressure ulcers: a retrospective review. Critical care nurse. 2011;31(4):30-43.
10. Ash D. An exploration of the occurrence of pressure ulcers in a British spinal injuries unit. Journal of Clinical Nursing. 2002;11(4):470-8.
11. Bergquist S, Frantz R. Pressure ulcers in community-based older adults receiving home health care: Prevalence, incidence, and associated risk factors. Advances in skin & wound care. 1999;12(7):339-51.
12. Cardoso MCdS, Caliri MHL, Hass VJ. Prevalência de úlceras de presão em pacientes críticos internados em um hospital universitário. REME rev min enferm. 2004;8(2):316-20.
13. Garber SL, Rintala DH. Pressure ulcers in veterans with spinal cord injury: a retrospective study. Journal of rehabilitation research and development. 2003;40(5):433-42.
14. Gardiner JC, Reed PL, Bonner JD, Haggerty DK, Hale DG. Incidence of hospital‐acquired pressure ulcers‐a population‐based cohort study. International wound journal. 2014.
15. Hyun S, Li X, Vermillion B, Newton C, Fall M, Kaewprag P, et al. Body Mass Index and Pressure Ulcers: Improved Predictability of Pressure Ulcers in Intensive Care Patients. American Journal of Critical Care. 2014;23(6):494-501.
16. Jones KR, Fennie K. Factors influencing pressure ulcer healing in adults over 50: an exploratory study. Journal of the American Medical Directors Association. 2007;8(6):378-87.
17. Lewis GM, Pham TN, Robinson E, Otto A, Honari S, Heimbach DM, et al. Pressure ulcers and risk assessment in severe burns. Journal of Burn Care & Research. 2012;33(5):619-23.
18. New PW, Rawicki HB, Bailey MJ. Nontraumatic spinal cord injury rehabilitation: pressure ulcer patterns, prediction, and impact. Archives of physical medicine and rehabilitation. 2004;85(1):87-93.
19. Pedrosa IL, Silva MSML, de Araújo AA, Schwanke CHA, DeCarli GA, Gomes I. Pressure ulcers in elders and in non-elders: a historical cohort study. Online Brazilian Journal of Nursing. 2014;13(1):82-91.
20. Rabadi MH, Vincent AS. Do vascular risk factors contribute to the prevalence of pressure ulcer in veterans with spinal cord injury? The journal of spinal cord medicine. 2011;34(1):46-51.

21. Schue RM, Langemo DK. Pressure ulcer prevalence and incidence and a modification of the Braden Scale for a rehabilitation unit. Journal of WOCN. 1998;25(1):36-43.
22. Spittle M, Collins R, Conner H. The incidence of pressure sores following lower limb amputations. Practical Diabetes International. 2001;18(2):57-61.
23. Boettger JE. Effects of a pressure-reduction mattress and staff education on the incidence of nosocomial pressure ulcers. Journal of Wound Ostomy & Continence Nursing. 1997;24(1):19-25.
24. Cole L, Nesbitt C. A three-year multiphase pressure ulcer prevalence/incidence study in a regional referral hospital. Ostomy Wound Management. 2004;50:32-41.
25. Sheerin F, Gillick A, Doyle B. Pressure ulcers and spinal-cord injury: incidence among admissions to the Irish national specialist unit. J Wound Care. 2005;14(3):112-5.
26. Rennert R, Golinko M, Yan A, Flattau A, Tomic-Canic M, Brem H. Developing and evaluating outcomes of an evidence-based protocol for the treatment of osteomyelitis in stage IV pressure ulcers: a literature and wound electronic medical record database review. Ostomy/wound management. 2009;55(3):42.
27. Ham HW, Schoonhoven LL, Galer AA, Shortridge-Baggett LLM. Cervical Collar–Related Pressure Ulcers in Trauma Patients in Intensive Care Unit. Journal of Trauma Nursing. 2014;21(3):94-102.
28. Jin Y, Piao J, Lee SM. Evaluating the Validity of the Braden Scale Using Longitudinal Electronic Medical Records. Research in nursing & health. 2014.
29. Robitaille C, Dai S, Waters C, Loukine L, Bancej C, Quach S, et al. Diagnosed hypertension in Canada: incidence, prevalence and associated mortality. Canadian Medical Association Journal. 2012;184(1):E49-E56.
30. Sadeghi B, White RH, Maynard G, Zrelak P, Strater A, Hensley L, et al. Improved coding of postoperative deep vein thrombosis and pulmonary embolism in administrative data (AHRQ patient safety indicator 12) after introduction of new ICD-9-CM diagnosis codes. Medical care. 2015;53(5):e37-e40.
31. Quan H, Eastwood C, Cunningham CT, Liu M, Flemons W, De Coster C, et al. Validity of AHRQ patient safety indicators derived from ICD-10 hospital discharge abstract data (chart review study). BMJ open. 2013;3(10):e003716.
32. Rosen AK, Itani KM, Cevasco M, Kaafarani HM, Hanchate A, Shin M, et al. Validating the patient safety indicators in the Veterans Health Administration: do they accurately identify true safety events? Med Care. 2012;50(1):74-85.
33. Borzecki AM, Kaafarani HM, Utter GH, Romano PS, Shin MH, Chen Q, et al. How valid is the AHRQ patient safety indicator “postoperative respiratory failure”? J Am Coll Surg. 2011;212(6):935-45.
34. Chen Q, Rosen AK, Cevasco M, Shin M, Itani KM, Borzecki AM. Detecting patient safety indicators: how valid is “foreign body left during procedure” in the Veterans Health Administration? J Am Coll Surg. 2011;212(6):977-83.
35. Koch CG, Li L, Hixson E, Tang A, Phillips S, Henderson JM. What are the real rates of postoperative complications: elucidating inconsistencies between administrative and clinical data sources. Journal of the American College of Surgeons. 2012;214(5):798-805.
36. Lyder CH, Wang Y, Metersky M, Curry M, Kliman R, Verzier NR, et al. Hospital‐Acquired Pressure Ulcers: Results from the National Medicare Patient Safety Monitoring System Study. Journal of the American Geriatrics Society. 2012;60(9):1603-8.
37. Fogerty M, Guy J, Barbul A, Nanney LB, Abumrad NN. African Americans show increased risk for pressure ulcers: a retrospective analysis of acute care hospitals in America. Wound repair and regeneration. 2009;17(5):678-84.
38. Kröger K, Niebel W, Maier I, Stausberg J, Gerber V, Schwarzkopf A. Prevalence of pressure ulcers in hospitalized patients in Germany in 2005: data from the Federal Statistical Office. Gerontology. 2009;55(3):281-7.

39. Ackroyd-Stolarz S, Bowles SK, Giffin L. Validating administrative data for the detection of adverse events in older hospitalized patients. Drug, healthcare and patient safety. 2014;6:101.
40. Polancich S, Restrepo E, Prosser J. Cautious use of administrative data for decubitus ulcer outcome reporting. American Journal of Medical Quality. 2006;21(4):262-8.
41. Meddings JA, Reichert H, Hofer T, McMahon LF. Hospital report cards for hospital-acquired pressure ulcers: how good are the grades? Ann Intern Med. 2013;159(8):505-13.
42. Berlowitz DR, Brandeis GH, Brand HK, Halpern J, Ash AS, Moskowitz MA. Evaluating pressure ulcer occurrence in long-term care: pitfalls in interpreting administrative data. Journal of clinical epidemiology. 1996;49(3):289-92.
43. Barczak CA, Barnett RI, Childs EJ, Bosley LM. Fourth national pressure ulcer prevalence survey. Advances in skin & wound care. 1997;10(4):18-32.
44. Catherine VanGilder M, Amlung S, Harrison P, Meyer S. Results of the 2008–2009 International Pressure Ulcer Prevalence™ Survey and a 3-year, acute care, unit-specific analysis. Ostomy Wound Management. 2009;55(11):39-45.
45. Quan H, Khan N, Hemmelgarn BR, Tu K, Chen G, Campbell N, et al. Validation of a case definition to define hypertension using administrative data. Hypertension. 2009;54(6):1423-8.
46. Chen G, Khan N, Walker R, Quan H. Validating ICD coding algorithms for diabetes mellitus from administrative data. Diabetes research and clinical practice. 2010;89(2):189-95.



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4,6,7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,6,7
Bias	9	Describe any efforts to address potential sources of bias	12
Study size	10	Explain how the study size was arrived at	7, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8, Table 2
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	na
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8,9
		(*b*) Report category boundaries when continuous variables were categorized	na
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8,9,10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Validation of two case definitions to identify pressure ulcers using hospital administrative data

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Title: Validation of two case definitions to identify pressure ulcers using hospital administrative data

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ABSTRACT

Objective: Pressure ulcer development is quality of care indicator, as pressure ulcers are potentially preventable. Yet pressure ulcer is a leading cause of morbidity, discomfort, and additional healthcare costs for inpatients. Methods are lacking for accurate surveillance of pressure ulcer in hospitals to track occurrences and evaluate care improvement strategies. The main study aim was to validate hospital discharge abstract database (DAD) in recording pressure ulcers against nursing consult reports, and to calculate prevalence of pressure ulcers in Alberta, Canada in DAD. We hypothesized that a more inclusive case definition for pressure ulcers would enhance validity of cases identified in administrative data for research and quality improvement purposes.

Setting: A cohort of patients with pressure ulcers were identified from enterostomal (ET) nursing consult documents at a large university hospital in 2011.

Participants: There were 1217 patients with pressure ulcers in ET nursing documentation that were linked to a corresponding record in DAD to validate DAD for correct and accurate identification of pressure ulcer occurrence, using two case definitions for pressure ulcer.

Results Using pressure ulcer Definition 1 (7 codes), prevalence was 1.4% and using Definition 2 (29 codes) prevalence was 4.2% after adjusting for misclassifications. The results were lower than expected. Definition 1 sensitivity was 27.7% and specificity was 98.8%, while definition 2 sensitivity was 32.8% and specificity was 95.9%. Pressure ulcer in both DAD and ET consultation increased with age, number of comorbidities, and length of stay.

Conclusion DAD underestimates pressure ulcer prevalence. Since various codes are used to record pressure ulcers in DAD, the case definition with more codes captures more pressure ulcer cases, and may be useful for monitoring facility trends. However, low sensitivity suggests that this data source may not be accurate for determining overall prevalence, and should be cautiously compared to other prevalence studies.

Strengths and limitations of this study

- We examined a large sample of patients for prevalence of pressure ulcers against enterostomal specialist consult descriptions to derive and validate a case-definition in disease classification codes.
- This study adds evidence of underestimation of pressure ulcer prevalence in administrative hospital data that could potentially be improved with more specific documentation and coding.
- A potential bias may be present from use of enterostomal nurse consultation notes that included mostly severe (stage III, IV and unstageable) pressure ulcers.
- The descriptive textual database created in this study is the foundation for future work on auto-detection of pressure ulcers in hospital records, to enhance the accuracy of prevalence estimates.

BACKGROUND

The development of a pressure ulcer (also called pressure injury) has been considered an indicator for quality of care, as pressure ulcers are potentially preventable, a leading cause of morbidity for inpatients,(1) and is a cause of substantial discomfort, prolonged hospitalizations, additional healthcare costs, and in some cases, death.(1) The National Pressure Ulcer Advisory Panel defines a pressure ulcer as "a localized injury to the skin and/or underlying tissue over a bony prominence, as a result of pressure, or pressure in combination with shear".(2) The severity of pressure ulcers can vary from skin erythema to full thickness tissue loss, with damage extending into muscle and bone.(2) It is estimated that pressure ulcers affect 250,000 to 500,000 patients, with an annual prevalence of 21-26% in health-care institutions in Canada.(3, 4) In the USA, pressure ulcer prevalence ranged from 10 to 18% in general acute care, 2.3 to 28% in long term care, and 0 to 29% in home care between 1990 and 2000.(5) In a recent review of international studies, pressure ulcer prevalence in acute care was estimated at 6 to 18.5% (6). As more severe cases require intensive treatments, have a prolonged healing time and are associated with higher incidence of complications,(7) the estimated cost of treatment varies from £1,214 to £14,108 per case in the UK,(7) and $124,327 to $129,248 USD in the USA for stage IV pressure ulcers.(8) In Canada, the estimated average monthly cost of pressure ulcer management among individuals with a spinal cord injury was $4,475 CDN in 2010.(9)

To date, information about pressure ulcers has been primarily obtained through cross-sectional surveys, incident reports, and chart reviews. Surveys, incident reports, and reporting systems, such as the NHS National Safety Thermometer in the UK, involve voluntary reporting which can result in inaccurate and under-reported data (10). The medical chart has been considered the "reference standard" as a source of research and quality improvement data due to the clinical information it contains. Thus retrospective reviews of medical records have been undertaken to identify prevalence and incidence of pressure ulcers as well as patient characteristics and associated risk factors among various patient populations,(4, 11-24) evaluate preventive and management strategies,(25-29) and evaluate the Braden scale in assessing risk for pressure ulcer development.(30) Chart reviews and prospective studies involving physical assessment are costly and time-consuming, thus other data sources are needed for surveillance.

Taking into account these barriers, administrative health data has been used as an alternate data source for pressure ulcer epidemiology and surveillance. Administrative health data is routinely-collected and population-based and can offer a more comprehensive picture of view of large population.(31) These data are collected by certified coding specialists (2-year Health Information Management diploma) who extract information about conditions and procedures from hybrid paper and electronic inpatient health records. They then assign World Health Organization International Disease Classification codes 10th version, Canada (ICD-10-CA). As administrative health data is collected for purposes other than research, it may be limited in its generalizability, continuity, accuracy, and completeness.

To date, several studies have used administrative health data to determine adverse events.(32-37) Some studies in the US have used the national Medicare Patient Safety Monitoring System database to determine the national and state incidence of hospital-acquired pressure ulcers,(38) and the 2003 Nationwide Inpatient Sample database to identify risk factors for pressure ulcer development among

African Americans.(39) One study examined trends in the prevalence and localization of pressure ulcers and comorbidities among hospitalized patients in Germany from 2005 to 2011 by using nationally-collected hospital data.(40) While administrative health data has been found to be valid in one study for identifying adverse events, including pressure ulcers, among older hospitalized patients,(41) findings from other studies indicated that administrative health data may not be reliable for examining pressure ulcer development among hospitalized patients, (42-43) and occurrence in long-term care.(44)

In consideration of the paucity and discrepancies in the literature, the purpose of our study was to validate Canadian administrative health data, also called hospital discharge abstract database (DAD), for determining if DAD could be used for pressure ulcer epidemiological studies and surveillance of pressure ulcers for quality improvement. However, the ICD-10-CA codes in DAD include those specific to pressure ulcer only, as well as those which refer to more generic skin conditions and may indeed be used for the coding of pressure ulcer. There is currently no standard for coding pressure ulcer in DAD. Our three specific objectives were 1) to validate DAD in recording pressure ulcer, 2) to calculate prevalence of pressure ulcer using DAD and 3) to adjust the prevalence to account for DAD validity. We hypothesized that a more inclusive case definition for pressure ulcers would enhance validity of cases identified in administrative data for research and quality improvement purposes.

MATERIALS AND METHODS

Study design

Our study team completed a cross-sectional retrospective analysis of enterostomal therapy (ET) nursing documentation and DAD independently to identify every pressure ulcer occurrence documented in each source for the year of 2011 (period prevalence). The DAD collects information from the patient's chart for each hospital discharge through professional coders. Validation was achieved by comparing it to the "reference standard" of data abstracted from wound care documentation by ET nurses. Unlike the existing literature, our study draws on Canadian data, and validates DAD by comparing it to documentation by ET nurses, which is likely to be the most accurate "reference standard" of chart recording on pressure ulcer management.

ET nurses are registered nurses who have received additional training to specialize in the provision of wound (including pressure ulcer), ostomy, and continence care. ET nurses are wound care specialists who are often present in larger hospitals to consult for treatment guidelines. ET nurse consults occur for more advanced pressure ulcers and therefore, more detailed documentation is typically present. Each occurrence from the ET nursing documentation was linked to its corresponding record in DAD through personal unique identifier (personal health number), in order to validate DAD for correct and accurate identification of pressure ulcer occurrence. We validated and compared two DAD coding definitions (Table 1) and calculated sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV).

Setting and study population

This study was conducted at a tertiary referral university hospital situated in a large city in Canada. It is one of the country's largest medical facilities with over 1000 acute inpatient beds.

Data sources

Enterostomal nurse documentation

We obtained nursing documentation on inpatients that received a consultation with an ET nurse (here on referred to as "ET nurse consults") in the year of 2011. Patients with pressure ulcers may be referred for ET nurse consults in our facility. Therefore, ET nurse consults were chosen as the most accurate way to identify actual pressure ulcer occurrences in the hospital. These would include but are not limited to: pressure ulcers, diabetic foot ulcers, venous leg ulcers, and other skin conditions.

Table 1. International Classification of Diseases 10th Version, Canada (ICD-10-CA) Codes

Definition 1
L89 Decubitus [pressure] ulcer and pressure area
L89.0 Stage I decubitus ulcer and pressure area
L89.1 Stage II decubitus [pressure] ulcer
L89.2 Stage III decubitus [pressure] ulcer
L89.3 Stage IV decubitus [pressure] ulcer
L89.8o Decubitus [pressure] ulcer, unstageable
L89.9 Decubitus ulcer and pressure area, unspecified

Definition 2
L89 Decubitus [pressure] ulcer and pressure area
L89.0 Stage I decubitus ulcer and pressure area
L89.1 Stage II decubitus [pressure] ulcer
L89.2 Stage III decubitus [pressure] ulcer
L89.3 Stage IV decubitus [pressure] ulcer
L89.8o Decubitus [pressure] ulcer, unstageable
L89.9 Decubitus ulcer and pressure area, unspecified
L97 Ulcer of lower limb, not elsewhere classified
L98.4 Chronic ulcer of skin, not elsewhere classified
S00 Superficial injury of head
S01 Open wound of head
S10 Superficial injury of neck
S11 Open wound of neck
S20 Superficial injury of thorax
S21 Open wound of thorax
S30 Superficial injury of abdomen, lower back and pelvis
S31 Open wound of abdomen, lower back and pelvis7.4
S40 Superficial injury of shoulder and upper arm
S41 Open wound of shoulder and upper arm
S50 Superficial injury of forearm

S51 Open wound of forearm
S60 Superficial injury of wrist and hand
S61 Open wound of wrist and hand
S70 Superficial injury of hip and thigh
S71 Open wound of hip and thigh
S80 Superficial injury of lower leg
S81 Open wound of lower leg
S90 Superficial injury of ankle and foot
S91 Open wound of ankle and foot

All of these consult requests are stored in a binder and maintained by the ET nursing team. Every ET nurse consult from the binder from 2011 was included in our study.

A medical student was trained by the principal investigator, who has expertise on pressure ulcer, on how to review the consult documentation to determine whether the wound(s) of interest was a pressure ulcer. The medical student analyzed each consult to identify those that described a pressure ulcer. Documentation from follow-up consults and duplicate consults were treated as one consult. For consult documentation that did not clearly indicate whether a pressure ulcer was being treated, the respective medical chart was obtained and reviewed by the medical student and principal investigator to determine whether a pressure ulcer was being treated. Consultations regarding wounds unrelated to pressure ulceration were excluded from our sample OR categorized as not pressure ulcer-related.

Included consultations concerning a pressure ulcer were then categorized by the location of the pressure ulcer. The anatomic categories included sacral ulcers, leg ulcers, ankle ulcers, heel ulcers, foot ulcers, and other ulcers. Patients with pressure ulcer in multiple locations had each ulcer entered separately in our database.

A trained medical student extracted the following information: patient hospital identification code, whether the consultation was pressure-ulcer related, location(s) of the pressure ulcer(s), and their severity. This information was used as our “reference standard” to verify the existence of pressure ulcers among the patients included in the study, which were then compared to the DAD data of the corresponding patients.

Discharge Abstract Data

This hospital’s DAD was obtained from the data repository managed by the region’s single health authority. This repository integrates data from multiple source systems, linking them as well as aggregating them to support measurement, reporting, and survey purposes. For each discharge, DAD abstracts and summarizes demographic, clinical, and administrative information such as date and time of admission, date of discharge, length of stay, and a maximum of 50 diagnostic codes (ICD-10-CA) and 20 procedure codes. To identify cases of pressure ulcer(s) in DAD for the year 2011, we used an ICD-10 coding definition that was developed by a group of wound care clinicians, ET nurses and nurse researcher. The process involved independent review of the ICD-10 codes by each of these people to identify codes which they considered to be related to pressure ulcers. Then a meeting was held to

discuss the identified codes for pressure ulcers. Ultimately, we decided to test two coding definitions. One definition is more specific (with only L89 codes), and should yield greater detection accuracy. The second definition is more inclusive (with L89 and other non-specific codes for wounds) and will likely capture a larger number of cases. The ICD-10 codes used for both definitions included in our study are presented in Table 1.

Linkage

Consultation data was linked with DAD using each patient's personal health number (PHN). To ensure that we are linking each consultation to the correct admission, we decided to only link consultations with the admission during which the consultation occurs. In other words, our linkage criteria specified that the consultation date must fall within the admission and discharge dates.

Statistical Analysis

Before conducing validation, we identified pressure ulcer cases in DAD. Using the two previously described ICD-10 coding definitions; we identified pressure ulcer cases in discharge data for all admissions at the large university hospital in 2011, and calculated a pressure ulcer prevalence using each definition.

The existence of pressure ulcers was compared between the two databases, and we calculated measures of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for each definition. This allows us to compare the predictive accuracy of each definition. We then used sensitivity and PPV to adjust our preliminary prevalence. We adjusted overall prevalence and each stratified subgroup. Details of our adjustment method can be found in Appendix A. This adjusted prevalence represents what the prevalence would have been had there been perfect sensitivity and PPV. We decided to only adjust using sensitivity and PPV, due to the fact that we had a low number of positive cases. Adjustment by sensitivity, specificity, PPV, and NPV would have yielded nonsensical results.

All data analysis was conducted using SAS 9.3. SAS is analytical software that is well suited to working with large databases.

RESULTS

Our consultation data contained 1575 ET nurse consults. Of these 318 were found to be duplicates and 2 patients were under the age of 18. These records were removed. Thirty-eight were cases of diabetic ulcers. It was decided by the study team that diabetic ulcers would not be included and these cases were also removed. The remaining sample included 1217 unique ET nurse consults which were linked to their matching admission in DAD (Figure 1).

Comparing pressure ulcer information in DAD against that in consultation, we calculated sensitivity of 27.7%, specificity of 98.8%, PPV of 91.7% and NPV of 73.9% for definition one, and a sensitivity of 32.8%, a specificity of 95.9%, a PPV of 79.3% and a NPV of 74.6% for definition 2 (Table 2). Regardless of definition, validity of ICD coding for pressure ulcers was relatively stable across groups by age and sex.

However, validity of ICD coding improved with increased length of stay.

Table 2 Validity of Administrative Health Data for Pressure Ulcers Using Consultation as Reference Standard (N= 1217)

Definition 1 (7 ICD-10-CA codes)		Sensitivity	Specificity	PPV*	NPV*
Overall		27.7%	98.8%	91.7%	73.9%
Age	18 - 34	20.0%	96.1%	60.0%	80.3%
	35-64	32.0%	98.5%	88.9%	79.8%
	65 and over	25.4%	99.4%	96.7%	67.4%
Sex	Male	29.0%	98.4%	90.1%	73.3%
	Female	26.1%	99.2%	93.9%	74.6%
Length of stay	1 - 30 days	19.5%	99.7%	95.4%	78.4%
	31 - 90 days	35.9%	96.9%	90.2%	65.7%
	91 - 180 days	40.5%	90.0%	83.3%	55.1%
	181 days or more	36.4%	100.0%	100.0%	51.7%
Definition 2 (29 ICD-11-CA codes)		**Sensitivity**	**Specificity**	**PPV***	**NPV***
Overall		32.8%	95.9%	79.3%	74.6%
Age	18 - 34	40.0%	92.2%	60.0%	83.9%
	35-64	39.3%	95.6%	77.6%	81.2%
	65 and over	28.0%	96.4%	83.3%	67.5%
Sex	Male	34.4%	95.7%	80.0%	74.3%
	Female	30.7%	96.1%	78.3%	75.1%
Length of stay	1 - 30 days	23.8%	97.2%	74.6%	78.8%
	31 - 90 days	41.4%	92.6%	81.5%	66.7%
	91 - 180 days	46.0%	90.0%	85.0%	57.5%
	181 days or more	45.5%	86.7%	83.3%	52.0%

Note: PPV: Positive predictive value, NPV: negative predictive value

Table 3 shows the prevalence and adjusted prevalence of pressure ulcers in DAD, stratified by age, sex, and length of stay using both definitions. We see that the adjusted prevalence is approximately double overall, and for most stratifications. The stratified prevalence indicates males were more likely to have pressure ulcers compared with females, and that longer length of stay is correlated with higher pressure ulcer prevalence.

Table 3 Prevalence and Adjusted Prevalence of Pressure Ulcers in DAD

		Coded in DAD		Adjusted based on Sensitivity & PPV		
Definition 1		**Number of cases**	**Prevalence**	**Number of cases**	**Adjusted Prevalence**	**Sample Size**
Overall		163	0.4%	539	1.4%	38820
Age	18 - 34	9	0.1%	27	0.3%	8667

	35-64	69	0.4%	192	1.1%	16781
	65 and over	85	0.6%	324	2.4%	13372
Sex	Male	100	0.6%	311	1.9%	16724
	Female	63	0.3%	227	1.0%	22096
Length of Stay	0 - 30 days	57	0.2%	279	0.8%	36752
	31 - 90 days	74	4.3%	186	10.8%	1724
	91 - 180 days	22	8.5%	45	17.5%	258
	181 days or more	10	11.6%	27	31.9%	86

Definition 2		**Number of cases**	**Prevalence**	**Number of cases**	**Adjusted Prevalence**	**Sample Size**
Overall		670	1.7%	1620	4.2%	38820
Age	18 - 34	179	2.1%	269	3.1%	8667
	35-64	272	1.6%	537	3.2%	16781
	65 and over	219	1.6%	652	4.9%	13372
Sex	Male	437	2.6%	1016	6.1%	16724
	Female	233	1.1%	594	2.7%	22096
Length of Stay	0 - 30 days	504	1.4%	1580	4.3%	36752
	31 - 90 days	117	6.8%	230	13.4%	1724
	91 - 180 days	31	12.0%	57	22.2%	258
	181 days or more	18	20.9%	33	38.3%	86

Table 4 indicates pressure ulcer coding against age, sex, number of co-morbidities, and length of stay, in both DAD and consultation data. Based on odds ratios, we see that while pressure ulcer coding in DAD is similar between age groups, older patients are more likely to be coded with pressure ulcers in the nursing consultations. Further, males are significantly more likely to be coded with pressure ulcers in DAD, whereas, the difference between the sexes is minimal in the consultations. For both DAD and nursing consultations, coding of pressure ulcers increased as the patient presents a greater number of comorbidities, and a longer length of stay.

Table 4 Stratifications of Pressure Ulcer Cases in Discharge Abstract Data and in Nursing Consultations

Definition 1 (7 ICD-10-CA codes) Factors		**Pressure Ulcer Coded in DAD**			**Pressure Ulcer Found in Consultation**		
		Yes	**No**	**OR**	**Yes**	**No**	**OR**
Age	18 - 34	9	8658	1.00	15	51	1.00
	35-64	69	16712	3.97	150	410	1.24
	65 and over	85	13287	6.15	232	359	2.20
Sex	Male	100	16624	1.00	221	437	1.00
	Female	63	22033	0.48	176	383	0.91
Number of Comorbidities	0	0	5826		2	52	1.00

	1 - 3	11	18401	1.00	44	241	4.75
	4 - 6	26	9457	2.31	92	210	11.39
	7 - 9	39	2976	21.92	87	126	17.95
	10 or more	87	1997	72.88	172	191	23.41
Length of Stay	0 - 30 days	57	36695	1.00	210	613	1.00
	31 - 90 days	74	1650	28.87	128	162	2.31
	91 - 180 days	22	236	60.01	37	30	3.60
	181 days or more	10	76	84.71	22	15	4.28

Definition 2 (29 ICD-10-CA codes)		**Pressure Ulcer coded in DAD**			**Pressure Ulcer Found in Consultation**		
Factors							
		Yes	**No**	**OR**	**Yes**	**No**	**OR**
Age	18 - 34	179	8488	1.00	15	51	1.00
	35-64	272	16509	0.78	150	410	1.24
	65 and over	219	13153	0.79	232	359	2.20
Sex	Male	437	16287	1.00	221	437	1.00
	Female	233	21863	0.40	176	383	0.91
Number of Comorbidities	0	0	5826		2	52	1.00
	1 - 3	108	18304	1.00	44	241	4.75
	4 - 6	197	9286	3.60	92	210	11.39
	7 - 9	154	2861	9.12	87	126	17.95
	10 or more	211	1873	19.09	172	191	23.41
Length of Stay	0 - 30 days	504	36248	1.00	210	613	1.00
	31 - 90 days	117	1607	5.24	128	162	2.31
	91 - 180 days	31	227	9.82	37	30	3.60
	181 days or more	18	68	19.04	22	15	4.28

OR = Odds ratio

Lastly, Table 5 lists the eight most common locations of pressure ulcers from the nursing consultations. Of note, there were a wide range of pressure ulcer locations. The eight most common locations only accounted for 32.6% of all pressure ulcer cases. The most common location by far was trochanteric pressure ulcer.

Table 5. Frequency of pressure ulcer locations based on nursing consultations

Ulcer location	**Number of Cases**	**Prevalence**
Ankle	14	1.1%
Foot	10	2.5%
Heel	42	10.6%
Ischial	4	1.0%
Leg	24	6.0%
Sacral	13	3.3%

Trochanteric	282	71.0%
Other	8	2.1%
Total	397	100.0%

DISCUSSION

The objective of our study was to determine whether routinely collected administrative health data could be used for improved measurement of pressure ulcers. Since there is no standard code definition for pressure ulcer, we used expert consensus to determine two coding definitions from administrative health data to estimate the prevalence. Next, we validated these definitions against wound care documentation by ET nurses. After adjusting for misclassifications of pressure ulcers, using Definition 1 we found prevalence of 1.4% and using definition 2 we found a prevalence of 4.2%. Definition 1 had a sensitivity of 27.7% and a specificity of 98.8%, while Definition 2 had a sensitivity of 32.8% and a specificity of 95.9%. This means that the more specific Definition 1 more accurately defines cases at the expense of missing some positive cases. Further, Definition 2 includes more positive cases at the risk of a larger number of false positives. Both definitions show low sensitivity and high specificity. These findings indicate that administrative health data underestimates the prevalence of pressure ulcers. Although the more inclusive Definition 2 had slightly higher sensitivity compared to Definition 1, the low sensitivity reflects the potential for the high frequency of missed pressure ulcer cases.

Compared with other studies of pressure ulcer prevalence, using the same set of ICD-10 codes (Definition 1) our finding of 0.4% for unadjusted prevalence is lower than another Canadian study that reported 3.5% cross-sectional prevalence, which can produce an overestimation.(4) As well, our prevalence of 0.4% is substantially low relative to previous studies described above (3, 5). This can be attributed to several factors: the assumption that ET nurse consults likely included mostly the more severe (stage III, IV and unstageable) pressure ulcers while other studies included pressure ulcers of all severities, there were differences in the population(s) studied, and there were different methods and data sources used. For example, the review by Woodbury et al found an estimated pressure ulcer prevalence rate of 26% based on studies between 1990 and 2003 across a range of healthcare settings in Canada, including mostly pressure ulcers determined by clinical data versus coded data.(3) Similarly, Cuddigan et al found prevalence rates ranging from 10 to 18% from analyzing prevalence data spanning a decade (1990-2000) and across care settings, again, based on mostly direct examination or chart review data.(5) Our prevalence rate was based on administrative health data from one tertiary acute care institution over one year. With such wide variations in care settings and time frames, these differences in prevalence rates are not surprising.

Another explanation to account for the underestimated prevalence rate is the inherent nature of the administrative health data. Our finding of either 27.7% or 32.8% sensitivity indicates a large proportion of pressure ulcers are not captured in the administrative health data. While this is a high percentage of missing cases, it is not an unreasonable finding.(34) One of the primary purposes of collecting administrative health data is to inform resource utilization, thus database administrators in Canada use predefined classification codes to register conditions that contribute to the length of stay in the hospital. Thus, less severe pressure ulcers, namely those identified as stage I and II are unlikely to be abstracted

into the database. Rather, the low sensitivities mostly reflect the occurrence of stage III, IV and unstageable pressure ulcers, the most severe cases that would indeed lead to hospitalization or contribute to the length of stay. While an adjusted prevalence rate of 4.2% is relatively low when compared to the overall prevalence of all stages of pressure ulcers across various health care settings,(3) it is comparable to the prevalence rates of severe pressure ulcers found in acute care facilities in other studies.(4,45,46).

A unique feature of our study was defining the pressure ulcer cohort by ET nurse consults. This method ensured that clear pressure ulcer cases were included. As a result, there may have been more medical documentation in the health record on wound description and treatment on these clear cases of pressure ulcers. Therefore, we suspect there may have been a greater chance for ICD coding abstractors to detect the pressure ulcer when ET nurses are consulted for the more severe ulcerations. That being said, less severe pressure ulcer cases may have been missed when no formal consultation is made, which are often only recorded by nurses and not seen by ICD coding abstractors.

Administrative health data has been used for various purposes, including chronic disease surveillance, quality of care assessments, and population health reports. This data source has been found to be well-coded for hypertension(47) and diabetes.(48) Similarly for pressure ulcer, administrative data analysis may serve to identify the magnitude of prevalence and monitor annual trends to inform quality of care evaluations. Whether the purpose is to evaluate quality of care over time within the same institution, or to make comparisons between institutions, we need to ensure that the data is sufficiently standardized and its quality is comparable across jurisdictions. Maintaining data quality is particularly salient, as the sensitivity, specificity, and the negative and positive predictive values of the data sources impact their comparability of prevalence rates. Given the high predictive value, this data source could be used to screen for potential pressure ulcer cases, which can be verified and their causes identified through chart reviews. Furthermore, this process would generate a cohort of severe pressure ulcer cases for follow-up study.

We acknowledge that our study has some limitations. First, there are fundamental limitations when using administrative data for surveillance of conditions related to patient safety. Specifically, improved documentation can result in a higher frequency of reported cases, making it appear as though hospitals with a better documentation have worse performance. Similarly, Quan et al drew a conclusion in a chart review study validating ICD-10 hospital discharge abstract data for the Agency for Healthcare Research and Quality (AHRQ) patient safety indicators in hospital discharge abstract data.(33) Due to findings of low sensitivity, they recommended that caution be used when rates of patient safety indicators are presented for 'quality of care reporting' as under-coded data generates falsely low patient safety indicator rates. Our study supports that administrative data is problematic when used for patient safety indicator surveillance. This illustrates the need for widespread improvements in both documentation and data abstraction of pressure ulcer occurrences for accurate data reporting.

Another limitation is that this study was conducted in one institution in an urban area over one year thus it limiting generalizability, though this institution is one of the largest hospitals in Canada. An additional limitation is that we used ET documentation as the reference standard. Unfortunately, clear

staging of pressure ulcers was not consistently included in the consultation notes. While ET nurses may be the most knowledgeable about identifying, and treating pressure ulcers, at this study's setting, they are most often consulted for the more severe pressure ulcer cases. As such, there is potential for bias as our study findings were less likely to include cases of stage I and II pressure ulcers, limiting its applicability to capture all pressure ulcers. We recognize that not all hospitals may offer specialised wound care services like ET nurses further limiting our study's generalizability.

There are several key practice implications from our study. One is that pressure ulcers are not consistently coded using only the ICD-10 L89.x codes, but also codes for other skin injuries. Thus, there will be positive cases missed if only L89 codes are used, as evidenced by low sensitivity of Definition 1. Secondly, more pressure ulcer cases would also be captured by improved documentation to clearly state the presence of a pressure ulcer versus just wound description. Third, coding specialists should be trained to use only L89 codes for pressure ulcers. Lastly, as recommended by Backman, documentation by nurses or other health professions should be considered valid sources for ICD coding to accurately capture hospital-related adverse events, such as pressure ulcers. (4) Until these changes are made, a more inclusive case definition like Definition 2, may be useful to identify pressure ulcer cases.

FUTURE RESEARCH

To proceed with quality improvement interventions, better methods are needed to quickly and accurately identify pressure ulcers in hospital charts and in coded data. Chart review and even the process of coding patient data is time consuming and costly. Future research must include further validation of a case definition for pressure ulcer. Then, these validated cases can be used to develop algorithms for fast automated detection of pressure ulcer in electronic hospital chart data. Currently at our centre, a large (n=3000) review of randomly selected hospital charts is underway to evaluate prevalence and validate ICD-10 codes for pressure ulcer in a larger sample. Next steps include using the validated terminology that describes pressure ulcer to develop auto-detection algorithms. Auto-detection, both in post-discharge and real-time admissions, will enable more effective tracking of pressure ulcer for the best possible treatment and quality improvement strategies for prevention. Ultimately, the same research methods could then be applied to other adverse events for fast accurate measurement.

CONCLUSION

This study provides a case-definition for pressure ulcer surveillance in Canada using administrative health data. Our findings support the use of a more inclusive definition within administrative data for identifying pressure ulcers, specifically, the more severe ones (stage III, IV and unstageable) per NPUAP's staging system. It may be particularly useful for monitoring prevalence trends within a facility. However, low sensitivity of DAD for identification of pressure ulcer suggests that this data source may not be accurate for determining overall prevalence, and it should be used with caution if it is being compared to other prevalence studies.

Contributors

CH designed the study and data acquisition methods, led analysis, interpretation of data, and provided critical oversight of drafting and revising the manuscript. CH had final approval of the submission.
JJ performed analysis and interpretation of the data.
CE participated in interpretation of the data, drafting, revisions, and submission of the manuscript.
HW participated in drafting, critical appraisal, and revision of the manuscript.
BW performed the majority of data acquisition and participated in drafting, critical appraisal, and revision of the manuscript.
HQ contributed substantially to the conception and design of the study, the interpretation of data, critical appraisal and revision of the manuscript, and final approval for submission.

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Competing interests None declared

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REFERENCES

1. Redelings MD, Lee NE, Sorvillo F. Pressure ulcers: more lethal than we thought? Advances in Skin & Wound Care. 2005;18(7):367-72.
2. Panel NPUA. NPUAP Pressure Ulcer Stages/Categories [Available from: http://www.npuap.org/resources/educational-and-clinical-resources/npuap-pressure-ulcer-stagescategories/.
3. Woodbury MG, Houghton PE. Prevalence of pressure ulcers in Canadian healthcare settings. Ostomy Wound Management. 2004;50:22-39.
4. Backman C, Vanderloo SE, Miller TB, Freeman L, Forster AJ. Comparing physical assessment with administrative data for detecting pressure ulcers in a large Canadian academic health sciences centre. BMJ Open. 2016;6(10): e012490.
5. Cuddigan J, Berlowitz DR, Ayello EA. Pressure ulcers in America: prevalence, incidence, and implications for the future. Advances in Skin & Wound Care. 2001;14(4):208.
6. Tubaishat A, Papanikolaou P, Anthony D, Habiballah L. Pressure ulcers prevalence in the acute care setting: A systematic review 2000-2015. Clinical Nursing Research.2017;1:1-28.
7. Dealey C, Posnett J, Walker A. The cost of pressure ulcers in the United Kingdom. Journal of Wound Care. 2012;21(6):261-2, 4, 6.
8. Brem H, Maggi J, Nierman D, Rolnitzky L, Bell D, Rennert R, et al. High cost of stage IV pressure ulcers. The American Journal of Surgery. 2010;200(4):473-7.
9. Chan BC, Nanwa N, Mittmann N, Bryant D, Coyte PC, Houghton PE. The average cost of pressure ulcer management in a community dwelling spinal cord injury population. International Wound Journal. 2013;10(4):431-40.
10. Smith IL, Nixon J, Brown S, Wilson L, Coleman S. Pressure ulcer and wounds reporting in NHS hospitals in England part 1: Audit of monitoring systems. Journal of Tissue Viability. 2016;25(1):3-15.
11. Alderden J, Whitney JD, Taylor SM, Zaratkiewicz S. Risk profile characteristics associated with outcomes of hospital-acquired pressure ulcers: a retrospective review. Critical Care Nurse. 2011;31(4):30-43.
12. Ash D. An exploration of the occurrence of pressure ulcers in a British spinal injuries unit. Journal of Clinical Nursing. 2002;11(4):470-8.
13. Bergquist S, Frantz R. Pressure ulcers in community-based older adults receiving home health care: Prevalence, incidence, and associated risk factors. Advances in Skin & Wound Care. 1999;12(7):339-51.
14. Cardoso MCdS, Caliri MHL, Hass VJ. Prevalência de úlceras de presão em pacientes críticos internados em um hospital universitário. REME rev min enferm. 2004;8(2):316-20.
15. Garber SL, Rintala DH. Pressure ulcers in veterans with spinal cord injury: a retrospective study. Journal of rehabilitation research and development. 2003;40(5):433-42.
16. Gardiner JC, Reed PL, Bonner JD, Haggerty DK, Hale DG. Incidence of hospital‐acquired pressure ulcers‐a population‐based cohort study. International Wound Journal. 2014.
17. Hyun S, Li X, Vermillion B, Newton C, Fall M, Kaewprag P, et al. Body Mass Index and Pressure Ulcers: Improved Predictability of Pressure Ulcers in Intensive Care Patients. American Journal of Critical Care. 2014;23(6):494-501.
18. Jones KR, Fennie K. Factors influencing pressure ulcer healing in adults over 50: an exploratory study. Journal of the American Medical Directors Association. 2007;8(6):378-87.
19. Lewis GM, Pham TN, Robinson E, Otto A, Honari S, Heimbach DM, et al. Pressure ulcers and risk assessment in severe burns. Journal of Burn Care & Research. 2012;33(5):619-23.
20. New PW, Rawicki HB, Bailey MJ. Nontraumatic spinal cord injury rehabilitation: pressure ulcer patterns, prediction, and impact. Archives of Physical Medicine and Rehabilitation. 2004;85(1):87-93.

21. Pedrosa IL, Silva MSML, de Araújo AA, Schwanke CHA, DeCarli GA, Gomes I. Pressure ulcers in elders and in non-elders: a historical cohort study. Online Brazilian Journal of Nursing. 2014;13(1):82-91.
22. Rabadi MH, Vincent AS. Do vascular risk factors contribute to the prevalence of pressure ulcer in veterans with spinal cord injury? The Journal of Spinal Cord Medicine. 2011;34(1):46-51.
23. Schue RM, Langemo DK. Pressure ulcer prevalence and incidence and a modification of the Braden Scale for a rehabilitation unit. Journal of WOCN. 1998;25(1):36-43.
24. Spittle M, Collins R, Conner H. The incidence of pressure sores following lower limb amputations. Practical Diabetes International. 2001;18(2):57-61.
25. Boettger JE. Effects of a pressure-reduction mattress and staff education on the incidence of nosocomial pressure ulcers. Journal of Wound Ostomy & Continence Nursing. 1997;24(1):19-25.
26. Cole L, Nesbitt C. A three-year multiphase pressure ulcer prevalence/incidence study in a regional referral hospital. Ostomy Wound Management. 2004;50:32-41.
27. Sheerin F, Gillick A, Doyle B. Pressure ulcers and spinal-cord injury: incidence among admissions to the Irish national specialist unit. Journal of Wound Care. 2005;14(3):112-5.
28. Rennert R, Golinko M, Yan A, Flattau A, Tomic-Canic M, Brem H. Developing and evaluating outcomes of an evidence-based protocol for the treatment of osteomyelitis in stage IV pressure ulcers: a literature and wound electronic medical record database review. Ostomy/Wound Management. 2009;55(3):42.
29. Ham HW, Schoonhoven LL, Galer AA, Shortridge-Baggett LLM. Cervical Collar–Related Pressure Ulcers in Trauma Patients in Intensive Care Unit. Journal of Trauma Nursing. 2014;21(3):94-102.
30. Jin Y, Piao J, Lee SM. Evaluating the Validity of the Braden Scale Using Longitudinal Electronic Medical Records. Research in Nursing & Health. 2014.
31. Robitaille C, Dai S, Waters C, Loukine L, Bancej C, Quach S, et al. Diagnosed hypertension in Canada: incidence, prevalence and associated mortality. Canadian Medical Association Journal. 2012;184(1):E49-E56.
32. Sadeghi B, White RH, Maynard G, Zrelak P, Strater A, Hensley L, et al. Improved coding of postoperative deep vein thrombosis and pulmonary embolism in administrative data (AHRQ patient safety indicator 12) after introduction of new ICD-9-CM diagnosis codes. Medical Care. 2015;53(5):e37-e40.
33. Quan H, Eastwood C, Cunningham CT, Liu M, Flemons W, De Coster C, et al. Validity of AHRQ patient safety indicators derived from ICD-10 hospital discharge abstract data (chart review study). BMJ Open. 2013;3(10):e003716.
34. Rosen AK, Itani KM, Cevasco M, Kaafarani HM, Hanchate A, Shin M, et al. Validating the patient safety indicators in the Veterans Health Administration: do they accurately identify true safety events? Medical Care. 2012;50(1):74-85.
35. Borzecki AM, Kaafarani HM, Utter GH, Romano PS, Shin MH, Chen Q, et al. How valid is the AHRQ patient safety indicator “postoperative respiratory failure”? Journal of the American College of Surgeons. 2011;212(6):935-45.
36. Chen Q, Rosen AK, Cevasco M, Shin M, Itani KM, Borzecki AM. Detecting patient safety indicators: how valid is “foreign body left during procedure” in the Veterans Health Administration? Journal of the American College of Surgeons. 2011;212(6):977-83.
37. Koch CG, Li L, Hixson E, Tang A, Phillips S, Henderson JM. What are the real rates of postoperative complications: elucidating inconsistencies between administrative and clinical data sources. Journal of the American College of Surgeons. 2012;214(5):798-805.
38. Lyder CH, Wang Y, Metersky M, Curry M, Kliman R, Verzier NR, et al. Hospital‐Acquired Pressure Ulcers: Results from the National Medicare Patient Safety Monitoring System Study. Journal of the American Geriatrics Society. 2012;60(9):1603-8.

39. Fogerty M, Guy J, Barbul A, Nanney LB, Abumrad NN. African Americans show increased risk for pressure ulcers: a retrospective analysis of acute care hospitals in America. Wound Repair and Regeneration. 2009;17(5):678-84.
40. Kröger K, Niebel W, Maier I, Stausberg J, Gerber V, Schwarzkopf A. Prevalence of pressure ulcers in hospitalized patients in Germany in 2005: data from the Federal Statistical Office. Gerontology. 2009;55(3):281-7.
41. Ackroyd-Stolarz S, Bowles SK, Giffin L. Validating administrative data for the detection of adverse events in older hospitalized patients. Drug, healthcare and patient safety. 2014;6:101.
42. Polancich S, Restrepo E, Prosser J. Cautious use of administrative data for decubitus ulcer outcome reporting. American Journal of Medical Quality. 2006;21(4):262-8.
43. Meddings JA, Reichert H, Hofer T, McMahon LF. Hospital report cards for hospital-acquired pressure ulcers: how good are the grades? Annals of Internal Medicine. 2013;159(8):505-13.
44. Berlowitz DR, Brandeis GH, Brand HK, Halpern J, Ash AS, Moskowitz MA. Evaluating pressure ulcer occurrence in long-term care: pitfalls in interpreting administrative data. Journal of Clinical Epidemiology. 1996;49(3):289-92.
45. Barczak CA, Barnett RI, Childs EJ, Bosley LM. Fourth national pressure ulcer prevalence survey. Advances in Skin & Wound Care. 1997;10(4):18-32.
46. Catherine VanGilder M, Amlung S, Harrison P, Meyer S. Results of the 2008–2009 International Pressure Ulcer Prevalence™ Survey and a 3-year, acute care, unit-specific analysis. Ostomy Wound Management. 2009;55(11):39-45.
47. Quan H, Khan N, Hemmelgarn BR, Tu K, Chen G, Campbell N, et al. Validation of a case definition to define hypertension using administrative data. Hypertension. 2009;54(6):1423-8.
48. Chen G, Khan N, Walker R, Quan H. Validating ICD coding algorithms for diabetes mellitus from administrative data. Diabetes Research and Clinical Practice. 2010;89(2):189-95.

Figure 1. Flow diagram of pressure ulcer case selection from enterostomal therapy nurse consultations

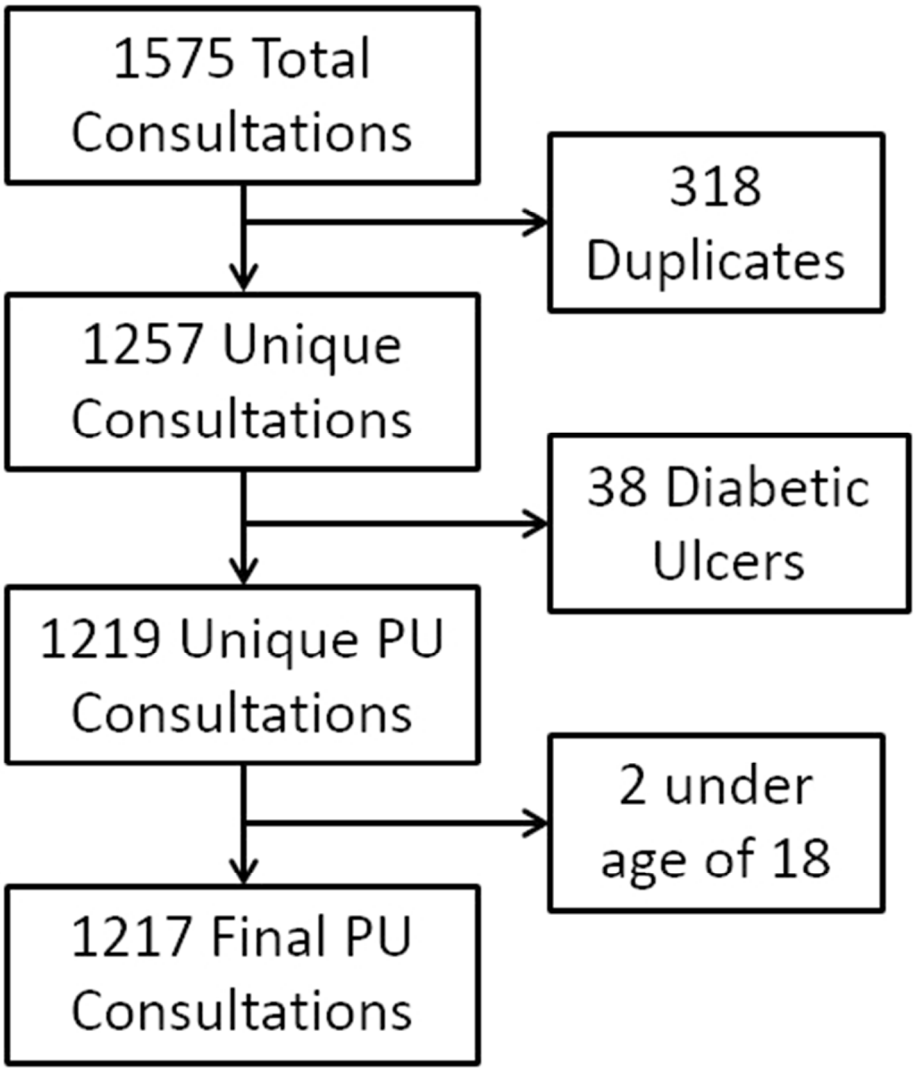

Figure 1. Flow diagram of pressure ulcer case selection from enterostomal therapy nurse consultations

39x46mm (300 x 300 DPI)

Appendix A

Prevalence Adjustment Method

Prevalence was adjusted for sensitivity and PPV. No adjustment was made for specificity and NPV. In order to perform the adjustment, we took the original number of cases and used sensitivity and specificity to calculate an adjusted number of cases. This adjusted number of cases was then divided by sample size (N) to obtain the adjusted prevalence. The formulas for our calculations of adjusted cases are included below.

Where:

Sen=TP/(TP+FN)
PPV=TP/(TP+FP)

TP= True positive
FN= False negative
FP= False positive

The cases we found using our definition is basically (TP+FP); cases identified correctly plus cases identified incorrectly. Adjustment was done to find (TP+FN); cases identified correctly plus all the cases missed incorrectly. Therefore, our method was:

1. (TP+FP)*PPV=TP
2. TP/Sen=(TP+FN)

This can also be expressed as:

1. (TP+FP)*(TP/(TP+FP))=TP
2. TP/(TP/(TP+FN))=(TP+FN)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4,6,7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,6,7
Bias	9	Describe any efforts to address potential sources of bias	12
Study size	10	Explain how the study size was arrived at	7, Figure 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	na
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	na
		(*e*) Describe any sensitivity analyses	na
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	na
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8, Table 2
		(b) Indicate number of participants with missing data for each variable of interest	na
Outcome data	15*	Report numbers of outcome events or summary measures	na
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8,9
		(*b*) Report category boundaries when continuous variables were categorized	na
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8,9,10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.